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Title

Evaluation of the Welch Allyn Microtympanometer compared to conventional examination methods.

The effect of general anaesthesia on microtympanograms and middle ear effusions.

The use of tympanometry in Pre-School audiological screening programme.

University

University of Cape Town

Degree

Master Of Medicine In Otolaryngology

Supervisor

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Aims of the Study

1) Test the accuracy of the Welch Allyn Microtympanometer against standard tympanometry.

2) Correlate preoperative clinical findings with:

- Microtympanometry
- Standard tympanometry

3) Assess influence of induction by gas anaesthesia on:

- Post-induction microtympanometry
- Intraoperative myringotomy findings

4) Assess the practicality of using the Welch Allyn Microtympanometer as a screening tool in Pre-School audiological testing.

Introduction

Otitis media with effusion (OME) may be defined as a chronic condition where there is an accumulation of non-purulent fluid in the middle ear. The time that the fluid has to be present in the middle ear for the condition to be considered chronic is usually taken as 12 weeks (Browning 1987).

OME is one of the most common chronic otological conditions of childhood (Toner and Mains 1988). The mucociliary system within the middle ear cleft is altered and serous or mucoid fluid accumulates in association with a negative pressure. Malfunction of the eustachian tube has been cited as the cause of this pressure change. Although signs of inflammation are absent, bacteria can be cultured in 50% of cases (Maw 1987). Many attempts have been made to develop methods for the early detection of the disorder as well as the prevention of disease progression.

Chronic OME is seen commonly in children with cleft palate and frequently occurs in association with chronic upper respiratory tract infection and conditions affecting the nose and sinuses. Its incidence peaks between the ages of two and seven years and there is a natural decline in prevalence between the ages of seven and ten years (Maw 1992). Twenty to thirty percent of children develop this condition under six years of age (Maw 1986). Ninety percent of effusions after otitis media, resolve within three months and this high spontaneous resolution rate appears to be mainly age related.

Unless children with OME are assessed systematically and repeatedly reassessed, a considerable proportion will undergo unwarranted surgery, with little or no resulting benefit (Editorial Lancet 1992).

The conventional procedures for the detection and identification of ear disease in children include case history information, pure tone audiometry and pneumatic otoscopy. Impedance audiometry (tympanometry) is regarded as a sensitive screening device and recently the microtymp has been introduced with its ease of operation and calibration, portability and low cost being cited as advantages over conventional tympanometers.

A prospective study was undertaken at Red Cross Childrens Hospital comparing the Welch Allyn microtymp to standard tympanometry and pneumatic otoscopy in predicting the presence of OME.

The poor relationship between ear disease and hearing loss has led to the conclusion that audiometry in general and screening audiometry in particular, is a poor choice for both identification and monitoring of ear disease.

Hearing loss of a significant magnitude is not a necessary component of the common ear diseases in children - this is true for acute otitis media and O.M.E.. Added to this is the problem that the highest prevalence of middle ear disease is in the young and often audiometrically untestable child.

Visual inspection also has its limitations. While many abnormalities of the M.E. system may be revealed, more subtle changes and deviations from normal are not universally detectable.

The best objective evidence of effusion is impaired T.M. mobility. This may be determined in two ways: directly by pneumotoscopy and indirectly by tympanometry. Each technique has a definite but a low susceptibility to error; when used in combination, the errors are reduced appreciably.

Pneumatoscopy requires proper equipment, skill and experience. Even experienced otoscopists have a sensitivity rate (detection of fluid when truly present) of no more than 94% and a specificity (no fluid when there truly is no fluid present) of between 74 and 78%.

The sensitivity and specificity rates were improved to 97% and 90% respectively when tympanometry was used in the diagnostic work-up (Cantekin et al 1980).

"Dry Tap" or negative myringotomy is when a child who is thought to have a middle ear effusion based on clinical and audiometric evidence, but is subsequently found to have a middle ear devoid of fluid when performing a myringotomy under anaesthetic.

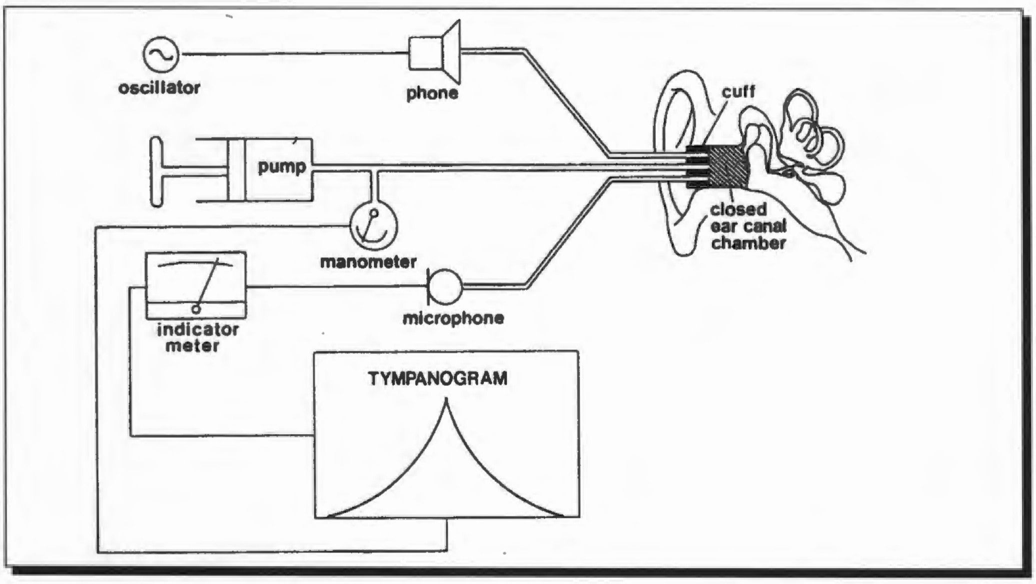
The incidence of a "dry tap" at myringotomy varies from 12% Grimaldi (1976) to 31% Mackinnon (1971). The reasons cited for this include the effect of nitrous oxide on the middle ear during surgery and the passive opening of the eustachian tube from increased nasopharyngeal pressure during positive pressure ventilation.

Tympanometry And Tympanograms

1) The Principle Of Tympanometry

The development of impedance audiometry has added new scope and dimension to clinical audiology. Based on the pioneering efforts of Metz (1946), subsequent workers have refined instrumentation, technique and interpretation to produce an invaluable tool for differential diagnosis.

The development of contemporary instrumentation for impedance audiometry has followed two essentially parallel paths. In the United States Zwislocki (1961) and his colleagues developed an electro**mechanical** bridge. In Europe Thomsen (1955), Terkildsen (1960) and others pioneered the application of the electro**acoustic** approach, culminating in the present commercially available electroacoustic bridge.



In the normal auditory system the middle ear is a cavity containing air at, or very close to, atmospheric pressure. The tympanic membrane is free to vibrate with maximum efficiency and to transmit acoustic energy over a wide spectrum to the cochlea. If the air pressure is varied in the external auditory canal, the tympanic membrane is stiffened, decreasing the transmission efficiency and increasing the reflection of sound. The graphic representation of TM efficiency (or compliance) as a function of the pressure differential across the TM is known as tympanometry.

A probe tip is sealed in the ear canal by means of a tightly fitting soft-tissue cuff, thus converting the external auditory canal to a closed chamber. The fine tip is pierced by three tubes connected to 1) an oscillator receiver delivering a fixed frequency tone, 2) a microphone monitoring the sound pressure level, and 3) a pump/manometer varying and measuring air pressure in the ear canal cavity.

The tone is presented at a given intensity and the sound pressure level in the external ear canal is continuously monitored while air pressure is continuously reduced from + 200 to - 400 mm H_2O, relative to atmospheric pressure. The tympanic membrane is stiffened by either positive or negative external canal air pressure, its impedance is increased and its compliance reduced, provided that the middle ear is normal. Sound absorption by the tympanic membrane (and the ossicular chain behind it), decreases accordingly and the sound pressure level in the canal rises. Since the sound pressure level is being continuously monitored, and since changes in the level are directly translatable into changes in tympanic membrane compliance, tympanic membrane compliance can be read continually as a function of changes in external canal pressure. This curve is referred to as a tympanogram.

2) Interpretation of Tympanograms

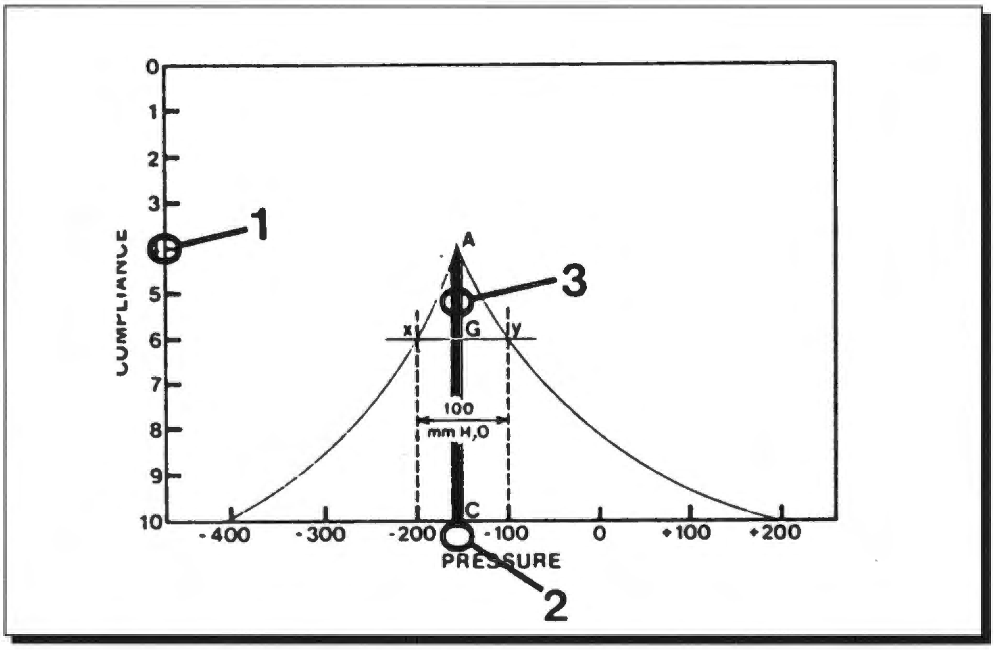
Four tympanometric variables have been used for the detection of middle ear disease. Static admittance is an estimate of the acoustic admittance at the plane of the tympanic membrane. It is estimated by subtracting the admittance at the probe tip when the ear canal is pressurized from the peak admittance. The clinical utility of the static admittance has not been widely been accepted, probably due to a lack of norms and standardized measurement procedures.

Equivalent ear canal volume (Vea) is a measure of the equivalent volume of air in front of the measurement probe. When a low probe frequency is employed, Vea is sensitive to tympanic membrane perforations that are accompanied by normal middle ear mucosa. When the middle ear mucosa is diseased, Vea frequently fails to detect perforations.

Tympanometric peak pressure (TPP) is the ear canal air pressure at which peak admittance occurs. Although TPP correlates with middle ear pressures, substantial differences can exist between TPP and the actual intratympanic pressure. Nevertheless, TPP has frequently been recommended as an indicator of middle ear pathology and as a criterion for medical referral.

The tympanometric gradient is a measure of the shape of the tympanogram in the vicinity of the peak. It has been shown to be useful in the detection of secretory otitis media. The optimal method to calculate gradient appears to be the determination of the pressure interval corresponding to a 50% reduction in peak eardrum admittance.

Tympanometry provides information about the air pressure behind the tympanic membrane and the static acoustic impedance. The latter is revealed by both the amplitude and the shape of the tympanogram.



Tympanogram indices:

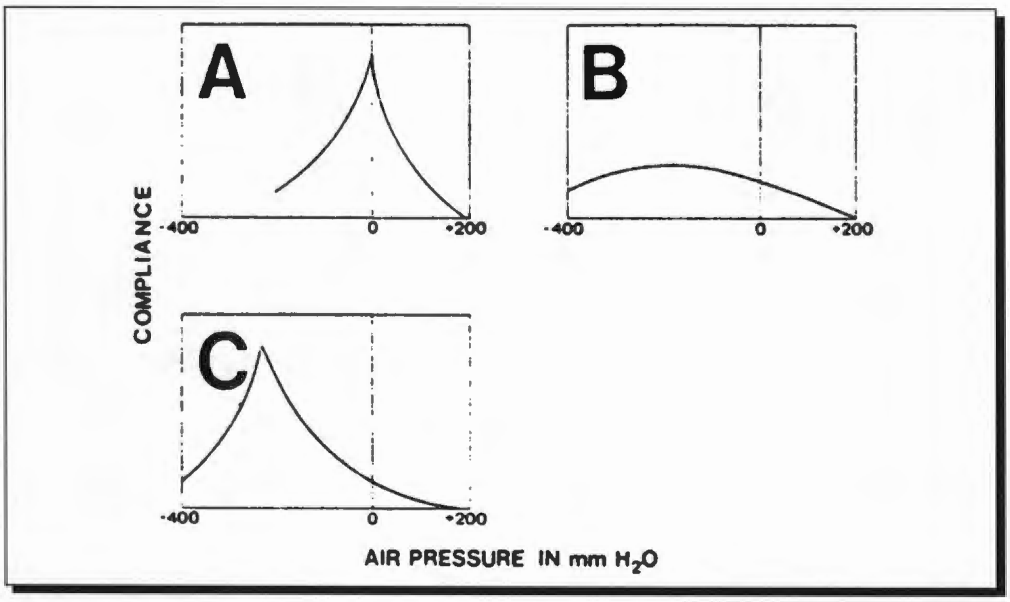
(1) Maximum compliance (distance AC)

(2) Tympanic Peak Pressure

(3) Gradient: Ratio AG / AC where AC is maximal height and AG the distance

3) Tympanogram Categories

Several categorizations of tympanometric curves have been devised, the first and most popular of which is the A B C classification of Jerger (Jerger 1970). Jerger's A curve shows a compliance peak between +/- 100 mm H_2O and suggests an air-filled tympanum. However, a shallow curve is not incompatible with an effusion. The B curve is flat, shows no peak, and is generally equated with an effusion. The C curve is peaked but displaced to the left below -100mm H_2O. C curves are difficult to interpret and most workers do not suspect effusion unless unless the peak is rounded and more negative than -150 to -200 mm H_2O (sometimes referred to as C2).



Bluestone et al (1973) grouped tympanograms into five groups on the basis of prediction of middle ear effusion. An even more detailed classification was used by Paradise and coworkers (1976) who described fifteen tympanometric profiles. Rounded curves (shallow gradient) are more likely to be associated with fluid than sharply peaked curves (steep gradient).

Brooks (1982) defined tympanograms in terms of its three major characteristics:

1) Height of the peak of the maximal compliance (units: cubic centimetres, acoustic ohms, or arbitrary in relative units from 0 to 10).

2) Location of the peak in relation to atmospheric pressure: an indirect expression of middle ear pressure, measured in mm H_2O.

3) Rate of change in curve height in the vicinity of the peak, i.e. gradient.

Feldman (1976) has suggested the use of a descriptive analysis which communicates the specific information revealed by tympanograms. Instead of a proliferation of classes and subclasses, a descriptive analysis conveys specific information about the:

1) specific peak pressure;

2) amplitude (normal, stiff or flaccid); and

3) shape of the tympanogram.

4) Diagnostic Interpretation of Tympanograms

A variety of conditions may produce alteration in the shape of the tympanogram or the position of its peak. A flattened tympanogram with a peak and a gradual gradient suggests that tympanic membrane compliance is reduced and that its response to air pressure change in the external canal is dampened.

A tympanogram whose peak is displaced toward the negative is suggestive of a reduction in middle ear pressure - a condition commonly attributed to Eustachian tube dysfunction.

An "open" tympanogram will be picked up when tympanic membrane compliance exceeds the recording capacity of the instrument. Such curves may be recorded from ears that are normal but are more frequently from others with atrophic scarring of the ear drum or disruption of the ossicular chain.

Tympanograms cannot be recorded from ears with perforated tympanic membrane (defects or open tympanostomy tubes). Obturating cerumen in the ear canal can mask a flattened tympanogram.

5) Reliability of Tympanometry

The identification of OME by acoustic impedance measurements is an objective procedure and should be more reliable than otoscopy as the latter is usually performed. However, validation of the various types of instruments is lacking. Even Jergers classification was not validated by either otoscopy or myringotomy. Therefore each type of electroacoustic impedance instrument needs to be validated either by an objective method such as myringotomy findings or by the observations of a validated otoscopist.

The development of portable electro-acoustic equipment has enabled measurements of the impedance of the middle ear to be made outside specialist clinics. This has made possible the diagnosis of middle ear disorder to be made on a wider scale than formerly. This raises a question whether this technique ought to be applied in screening of pre-school populations.

Various studies (Ferrer 1983) have indicated that the correlation between the usual screening tests carried out i.e. a form of sweep audiometry correlates very poorly with the results of impedance screening. This is due to the fact that both tests are testing for different conditions, which are linked. One tests for hearing loss (sweep audiometry) and the other for middle ear function (tympanometry) which does not always have an accompanying hearing loss.

It would normally be expected the sweep testing that occurs at, or about, school entrance should pick up the majority of cases with middle ear disorders. Numerous studies, however have shown that this is not so and it has been shown that the correlation between sweep testing and the prescence of negative middle ear pressure and reduced compliance is poor. (Ferrer 1983). It can thus be concluded that sweep testing could miss a large number of children with abnormal tympanograms. In spite of this, sweep testing is still widely used mainly because of the possibility of missing a case of sensorineural deafness.

Sensorineural deafness should be a rare dignosis at pre-school age as the majority of children with congenital sensorineural deafness should be picked up when the child is screened at infancy. After the age of 3 years, the main problem is not the detection of sensorineural deafness, but persistent cases of middle ear disease e.g. unresolved otitis media with effusion.

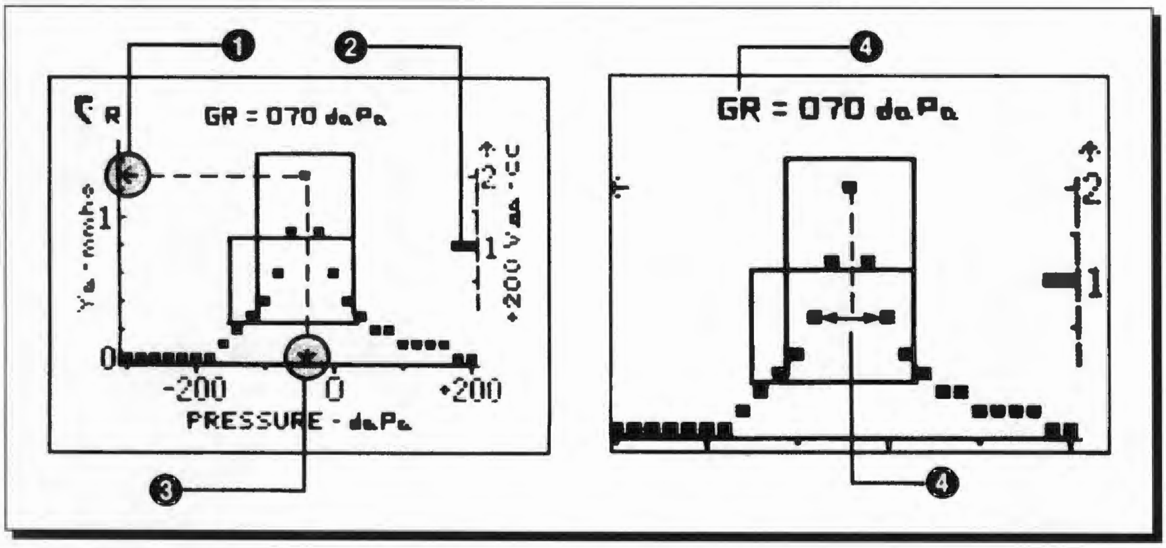
The biggest problem regarding impedance measurements is that no matter how carefully the parameters are set, an initial screen of any child population will reveal considerable numbers of cases with either flattened curves or high negative middle ear pressures which are going to resolve spontaneously - this could result in a serious overloading of the ENT system with temporary conditions.

6) Welch Allyn Microtympanometer

Advantages of the Welch Allyn Microtympanometer over standard audiometric tests are its portability, speed of use and cost. One of the objects of this study was to assess its accuracy in predicting OME as compared to existing instruments.

The microtymp is a single-component aural acoustic admittance meter that records a tympanogram with a 226 Hz probe tone (Welch Allyn Microtymp information pamphlet).

Four features of the microtymp can be used to evaluate the ear under test:



1) Static admittance (Peak Ya)

- This is a measure of the height of the tympanometric peak. Given appropriate norms, static admittance is a useful indicator of ME disease.

2) Equivalent ear canal volume (+ 200 Vea)

- This is the admittance value determined with an ear canal pressure of +200 da Pa. An abnormally high value suggests presence of a TM perforation or a patent tympanostomy tube.

3) Tympanometric peak pressure (TPP)

- This is the position of tympanometric peak on the pressure axis. TPP is an imprecise measure of the ME pressure. By itself, TPP is not an accurate indicator of ME disease.

4) Tympanometric gradient (GR)

- The gradient or width is a measure of the tympanometric peak. Defined as the pressure interval required for a 50% reduction of the peak eardrum admittance, tympanometric width is a good indicator of the prescence of ME effusion.

Table of Normal Values

(Margolis,R.H.and Heller,J.(1987))

	CHILDREN		ADULTS	
	Mean	Range	Mean	Range
Peak Ya (mmhos)	0,50	0,22 - 0,81	0,72	0,27 - 1,38
+200 Vea(cc)	0,74	0,42 - 0,97	11.05	0,63 - 1,46
TPP (daPa)	-30,4	-139 - +11	-18	-33 - 0
GR (daPa)	100	59 - 151	77	51 - 114

"Negative Myringotomy"

The stimulus to investigate the predictors of MEE was provided by the occasional occurence of the "negative myringotomy" - i.e. the child who has been assessed by an otologist who thinks that there is sufficient clinical and audiometric evidence of an effusion to justify performing a myringotomy under anaesthetic, but is subsequently found to have a M.E. devoid of fluid.

At Red Cross Hospital the appropriate clinical and occasionally audiometric assessment is performed on the morning of surgery, thereby excluding those cases who have changed in the period since assessment in the Out Patients Department. There, however, remains a number of cases where all evidence points towards the presence of a MEE and yet, at surgery, there is apparently no effusion. Negative myringotomy incidence has been reported as 12% (Grimaldi 1976); 14% (Orchik 1978); 17% (Shaw et al 1978); 20% (Haughton 1977); 21% (Cowan and Brown 1974); 30% (Black 1990) and 31% (MacKinnon 1971).

Various authors have investigated the effects of nitrous oxide anaesthesia on the middle ear. Thomsen (1965) first reported the ME pressure changes under nitrous oxide anaesthesia and concluded that nitrous inhalation will cause an increase in ME pressure which falls rapidly after a certain maximum ME pressure is reached - he attributed this to the opening of the Eustachian tube during yawning. Rasmussen (1967) noticed that ME pressure rose to between +200 mm and +400mm H_2O when a sudden drop in pressure occurred. He attributed this to the passive opening of the Eustachian tube, the time for which varied from less than 5 minutes to 20 minutes. He also noted that if anaesthesia continued, the pressure rose again to the previous level, when a further sudden drop in pressure occured - this cycle continued at regular intervals.

Rasmussen also demonstrated that the ME pressure increases rapidly only when Nitrous oxide is used. This did not occur when Halothane was used with or without Oxygen.

Pattersen and Bartlett (1976) found similar results using 70% Nitrous oxide and Singh and Kirk (1979) confirmed the above findings, except that the peak pressure was reached in a shorter period in most cases in children. They attributed it to the quick saturation of blood with nitrous oxide in children and felt other contributing factors might be the volume of tympanomastoid segments in children and the vascularity of the ME mucosa.

Nitous oxide (N_2O) is a tasteless, colourless gas commonly used as an anaesthetic. As induction and recovery occur rapidly with little or no adverse effects, it is considered to be one of the safest anaesthetics. Nitrous oxide is rapidly absorbed from the alveoli because it is extremely soluble in plasma. The gas does not combine with haemoglobin and is carried in the blood in physical solution only. The major part is excreted, unchanged, through the lungs within 2-3 minutes.

Nitrous oxide enters any air-filled cavity 30 times faster than the Nitrogen within the cavity can be resorbed. If the cavity has somewhat rigid walls, this differential rate of gas exchange results in a pressure increase within the cavity before equilibrium is established.

The question whether the ME pressure increase due to Nitrous oxide inhalation is sufficient to clear the ME of fluid remains debatable. Shaw, et al (1978) found that in 17% of their ears Nitrous oxide may have played a role.

Various authors have cited Nitrous oxide as the cause of their negative taps, whereas others (Bluestone 1973) believe that only fluid of low viscosity could be cleared from the ME.

The method by which the fluid leaves the ME is thought to be due to the properties and the effects of the Nitrous oxide as described above and secondly due to the passive opening of the Eustachian tube from increased nasopharyngeal pressure (Johnson et al 1980).

Patients And Methods

This study was undertaken to see if there is a practical way to provide a modified diagnostic service which would detect the persistent cases of middle ear disease and at the same time not overload the ENT service. The study was conducted in three parts.

Part One:

Microtympanometry vs Standard Tympanometry

In the first part of the study, the Welch Allyn Microtympanometer was compared to the standard tympanometer (GSI 28A). A total of 233 ears were evaluated by doing both Microtympanometry and standard tympanometry at the same examination.

The Welch Allyn Microtymp was used over a pressure change of +200 to -300 daPa (1 daPa = 1.04 mm H_20), with a 226 Hz probe tone and pump speed of 200 +/- 20 daPa/ second. The variables of Microtympanometry evaluated were static admittance, equivalent ear canal volume, tympanic peak pressure, gradient and Jerger typing. Standard tympanometry was performed using a GSI 28A tympanometer over a pressure change of +200 to -400 mm H_2O with a 256 Hz probe and was assessed in terms of the tympanic peak pressure, amplitude (relative units 0 to 10), shape (normal, broad, flat, peaked or notched) and Jerger typing.

Part Two:

Evaluation of Clinical Examination and Tympanometry as Predictors of OME (Red Cross Hospital Study)

In the second part of the study, a total of 103 ears were evaluated in a twelve month period from November 1992 to October 1993 at Red Cross Children's Hospital. All children booked for grommets with / without adenotonsillectomy were included in the study. All those cancelled for anaesthetic reasons and those with incomplete investigations done were excluded.

All candidates for the trial were examined by an Otologist in the ENT clinic on the morning of surgery. Ears were graded on clinical appearance alone as normal or abnormal. Using pneumatic otoscopy, the ears were graded as normal, definite middle ear effusion or uncertain.

A microtymp was done on the patient as well as a standard tympanogram and graded according to Jerger's modified classification into A, B, C1 or C2. Immediately after induction of anaesthesia, the microtymp was repeated and a myringotomy was performed. Fluid obtained was categorized as serous, glue or none obtained.

Part Three:

Barkly House Pre-School Screen

In the third part of the study, 118 children at Barkly House Pre-school were evaluated using clinical examination, Microtympanometry and a Welch Allyn audioscope which is an instrument that emits a 25dB signal over the frequencies of 500 Hz, 1 kHz, 2 kHz and 4 kHz at varying intervals.

The audioscope was used on those children of 4 years or older in a quiet side room at a screening level of 25 dB over the frequencies of 500 Hz, 1 kHz, 2 kHz and 4 kHz. Those under 4 years of age were therefore evaluated using clinical examination and Microtympanometry alone.

The ease of doing the audioscope was assessed as being easy, moderately difficult or impossible.

The protocol used in this part of the study was that those children found to have one or more of:

- abnormal T.M.'s as tested with pneumatic otoscopy
- high negative pressure or reduced static admittance on microtympanometry
- failed pure tone screen (Welch Allen audioscope at 25dB) at two or more frequencies, were re-tested six weeks after the first test. Similarly, after the second test, the children with persistent problems were re-tested three weeks later together with formal audiometry. Those children who still showed signs of problems were then referred to their G.P. for further management.

The procedure is summarized as follows:

Phase One:

- All children - the failures to be referred to phase two
- "Failures" = abnormal T.M.'s using pneumatic otoscopy
  = M.E. pressure < -250 mm H_2O and / or
  = static admittance of < 0,22 mmho
  = failed Pure Tone thresholds (Welch Allyn audioscope) in > 2 frequencies at 25 dB

Phase Two:

- Failures from phase one retested six weeks later and those failing according to the same criteria set above, were referred to phase three.

Phase Three:

- Failures from phase two reassessed three weeks later by combined examination by ENT surgeon (author) and an audiologist (Miss Tania Dunn) from Groote Schuur Hospital. Failures in this phase were sent to their General Practioners.

Findings And Results

Part One:

Microtympanometry vs Standard Tympanometry

In the first part of the study, comparing microtympanometry and standard tympanometry 233 ears were evaluated.

Analysis of the various parameters showed a wide spectrum of middle ear conditions, ranging from normality to Otitis Media with Effusion.

Tympanograms can be defined in terms of the height of the peak of maximal compliance. **Static admittance** is a measure of the height of the **microtympanometric** peak, as **amplitude** is the measure of the height of the **standard tympanometric** peak. Therefore, a comparison is made of these two parameters in the tables below:

Microtymp Parameters
(Total of 233 ears)

(1) Static Admittance	Number of Ears
Normal 0.22 - 0.81 mmhos	107
< 0.22 mmhos	20
> 0.81 mmhos	24
Flat (no peak)	82

Standard Tympanometry Parameters
(Total of 233 ears)

(1) Amplitude	Number of Ears
Normal 0.3 to 1.0 cc	109
0 to 0.2 cc	31
> 1.1 cc	16
Flat (no peak)	77

Microtymp Parameters
(Total of 233 ears)

(2) Tympanic Peak Pressure	Number of Ears
Normal -139 to +11 daPa	109
Flat (no reading)	82
< -139 daPa	42

(3) Jerger Typing		No of Ears
Type A	-100 to +100	101
Type B	No Peak	82
Type C_1	-101 to -199	23
Type C_2	-200 to -400	27

Standard Tympanometry Parameters
(Total of 233 ears)

(2) Tympanic Peak Pressure	Number of Ears
Normal -100 to +100	101
No Peak	77
-101 to -199	26
-200 to -400	29

(3) Jerger Typing		No of Ears
Type A	-100 to +100	101
Type B	No Peak	77
Type C_1	-101 to -199	26
Type C_2	-200 to -400	29

Regression of Static admittance in Microtympanometry and Amplitude in Standard tympanometry had a correlation coefficient of 0,75 which shows a very good correlation between those two parameters.

Regression of the absolute values of Microtymp Tympanic Peak Pressure and Standard Tympanogram Peak Pressure showed a coefficient of 0,73 which shows a very good correlation between those two parameters.

Jerger type was identical in 204 (88%) of the ears tested. (n = 233 ears):

- Type A - consistent in 93 ears
- Type B - consistent in 74 ears
- Type C_1 - consistent in 17 ears
- Type C_2 - consistent in 23 ears

An abnormally high Equivalent ear canal volume occurred only in the presence of atrophic T.M.s. When a perforation or a patent grommet tube was present, no seal could be obtained.

Part Two:

Red Cross Hospital Study

In the second part of the study, children between the age of 1 to 12 years with a mean age of 5,06 years (Std Dev 2,59 years), were evaluated in a twelve month period from November 1992 to October 1993 at Red Cross Childrens Hospital. A total of 103 ears of which 61,4 % were male were evaluated.

(1) **Pneumatic Otoscopy** (n = 103 Ears)	Number of Ears
Normal	4
Middle Ear Effusion	98
Uncertain	1

(2) **Microtymp Findings** (n = 103 Ears)		Number of Ears
Type A	-100 to +100	6
Type B	No Peak	82
Type C_1	-101 to -199	7
Type C_2	-200 to -400	8

Correlation between Microtymp and Pneumatic Otoscopy:

(1)		Pneumatic Otoscopy Findings (n = 103 Ears)		
		Normal	Middle Ear Effusion	Uncertain
Microtymp Type	A(6)	3	0	0
	B(82)	0	82	0
	C_1(7)	0	7	0
	C_2(8)	1	6	1

When the Microtymp was of type B, a diagnosis of middle ear effusion was made in 100% of cases. The only uncertainty was found with type C2 microtymp. Surprisingly, in all the type C1 microtymps a diagnosis of middle ear effusion was made with pneumatic otoscopy.

Standard tympanometry was performed at the same time as Microtympanometry:

(2)		Standard Tymp Jerger Type (n = 103 Ears)			
		A	B	C_1	C_2
Microtymp Jerger Type	A(6)	6	0	0	0
	B(82)	1	78	1	2
	C_1(7)	1	2	4	0
	C_2(8)	0	0	0	8

Type A corresponded in all 6 ears. Type B corresponded in 78 out of 82 ears (95%), type C1 corresponded in 4 out of 7 ears and type C2 corresponed in all 8 ears.

Once gas induction had occurred, a microtymp was repeated and compared to pre-anaesthetic microtymp findings:

(3)		Post-Induction Microtymp (n = 103 Ears)			
		A	B	C_1	C_2
Pre-anaesthetic Microtymp	A(6)	4	2	0	0
	B(82)	4	77	1	0
	C_1(7)	1	5	1	0
	C_2(8)	1	5	1	1

From the above table, the influence of positive pressure gas induction is evident in that 12 ears converted to type B after induction. Type B remained constant in 77 out of 82 ears (94%) and reverted to type A in 4 ears and C1 in 1 ear.

Fluid was found at myringotomy in 80 of the 103 ears (78%). The fluid was categorized into serous or glue according to its consistency.

(4)		**Pneumatic Otoscopy** **Pre-op Prediction of MEE** (n = 103 Ears)	
		No Fluid	Middle Ear Effusion
Myringotomy Findings	No Fluid	2	21
	Middle Ear Effusion	2	78
Sensitivity: 97% Specificity: 9% (Epstein et al 1988)			

(5)		Pre-Anaesthetic Microtymp Type (n = 103 Ears)			
		A	B	C_1	C_2
Myringotomy Findings	Dry(23)	2	16	3	2
	Serous(25)	4	13	3	5
	Glue(55)	0	53	1	1
Sensitivity: 90 % Specificity: 22 % (Epstein et al 1988)					

Microtymp gave correct predictions of myringotomy when type A and C1 were considered to indicate dry ears and C2 and B tympanograms to indicate effusions, in 77 (75%) of ears.

(6)		Post-Induction Microtymp Type (n = 103 Ears)			
		A	B	C_1	C_2
Myringotomy Findings	Dry(23)	4	17	1	1
	Serous(25)	4	20	1	0
	Glue(55)	2	52	1	0
Sensitivity: 90 % Specificity: 22 % (Epstein et al 1988)					

(7)		Standard Tymp Type (n = 103 Ears)			
		A	B	C_1	C_2
Myringotomy Findings	Dry(23)	3	14	3	3
	Serous(25)	5	13	1	6
	Glue(55)	0	53	1	1
Sensitivity: 91 % Specificity: 26 % (Epstein et al 1988)					

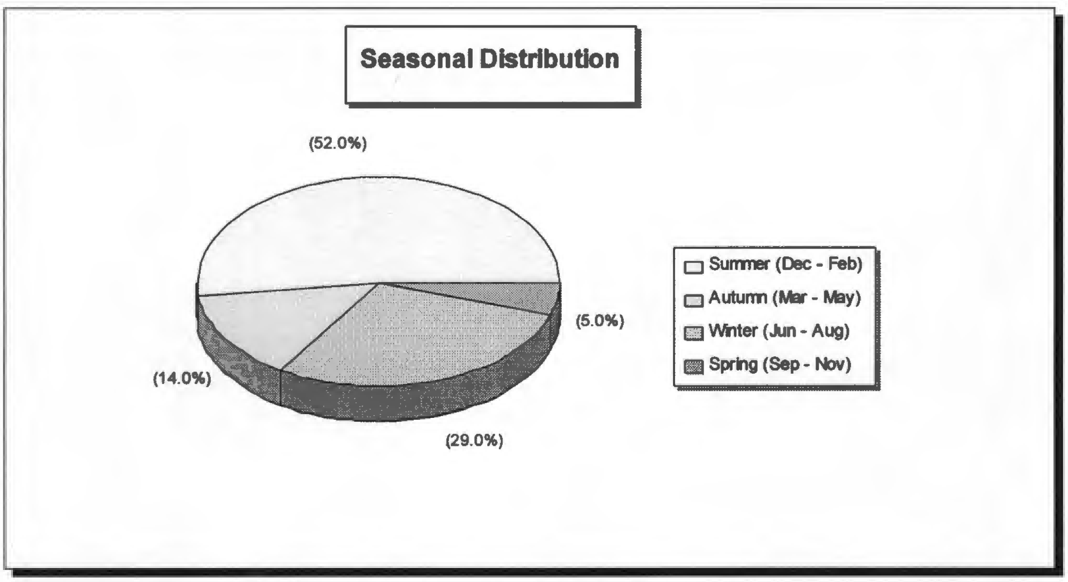
Standard tympanograms gave correct predictions of myringotomy in 79 (77%) of ears.

The "dry tap" incidence using:

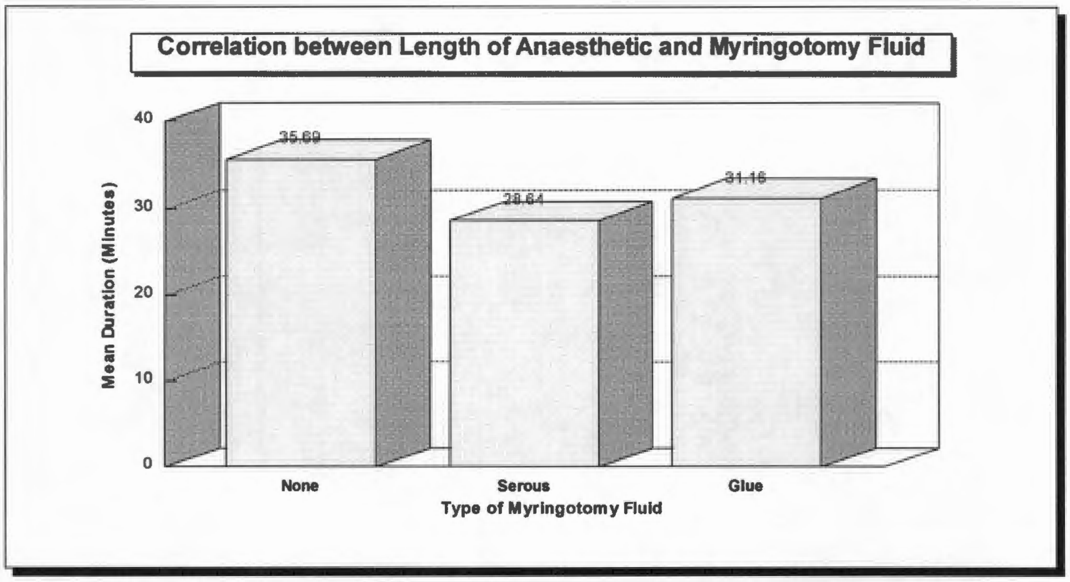
- Pneumatic otscopy = 21 out of 98 ears (21%)
- Pre-op microtymp = 16 out of 82 ears (19%)
- Standard tymps = 14 out of 80 ears (18%)

Middle ear ventilation tubes (grommets) were inserted into 101 of the 103 ears, this decision having been made on clinical grounds on the morning of surgery.

Tonsillectomy was performed simultaneously in 16 patients and adenoidectomy in 28 patients. Ventilation tubes had been inserted previously in 15 ears and tonsillectomy in 8 patients and adenoidectomy in 9 patients. The study was completed in a twelve month period from November 1992 to December 1993.



All cases had a gas induction and Nitrous oxide was used in all cases. Anaesthetic time varied from 15 to 87 minutes with a mean of 31,56 minutes. (Std Dev. 12,85 mins). There was no correlation between length of anaesthetic and type of fluid obtained at myringotomy.



54% of cases were intubated - these represented those cases who had concommitant tonsillectomy and / or adenoidectomy.

Part Three:

Barkly House Pre-School Screen

A total of 118 children ranging in age from 3 to 6 years with 52% girls and 48% boys were evaluated at Barkly House Pre-school.

Phase One:

All children present were evaluated at the first examination by pneumatic otoscopy and Microtympanometry. Children of 4 years or older were in addition screened with a Welch Allyn Audioscope.

Pneumatic Otoscopy (n = 236 ears)	Number of Ears
Normal	151
Abnormal (MEE)	65
Uncertain	20

Microtympanometry (n = 236 ears)	
	Number of Ears
Type A	124
Type B	31
Type C_1	47
Type C_2	34

Ease of Audioscope (n = 150 ears)	
	Number of Ears
Easy	137
Moderately Difficult	8
Impossible (therefore not Included)	5

Individual parameters of Audioscope (at 25 dB) (n=145 ears):

- 500 Hz negative in 31 ears
- 1000 Hz negative in 17 ears
- 2000 Hz negative in 11 ears
- 4000 Hz negative in 11 ears

Phase Two:

A total of 100 ears which had failed the first screening test were reassessed six weeks later.

Pneumatic otoscopy (100 ears):

- consistently normal in 23 ears
- consistently MEE in 30 ears
- consistently uncertain in 5 ears
- change from uncertain / MEE to normal in 26 ears
- change from normal to uncertain / MEE in 16 ears

Microtymp grading (Phase One vs Phase Two) 100 ears:

- consistently - Type A in 17 ears
  Type B in 18 ears
  Type C1 in 9 ears
  Type C2 in 10 ears

In 34 ears there had been an improvement in Jerger type and in 13 ears a worsening.

Audioscope findings:

- Ease of using the Audioscope was now 100% "easy" - most likely as a result of conditioning.
- A consistently negative response to audioscope was found:
  - at 500 Hz in 12 ears
  - at 1 kHz in 7 ears
  - at 2 kHz in 1 ear
  - at 4 kHz in 4 ears

Phase Three:

A total of 34 ears who had failed both the first and second screening tests were reassessed three weeks after phase two using clinical testing, formal audiometry using the Maeko AE Audiometer and Microtympanometry. Three ears had grommets / T.M. perforation and therefore could not be evaluated by Microtympanometry (therefore n=31).

Pneumatic Otoscopy (n = 31 ears)	Number of Ears
Normal	18
Abnormal (MEE)	6
Uncertain	7

Formal audiometry testing (Threshold > 20 dB):

- 250 Hz - 21 ears
- 500 Hz - 26 ears
- 1000 Hz - 11 ears
- 2000 Hz - 5 ears
- 4000 Hz - 11 ears
- 8000 Hz - 14 ears

Microtympanometry: (3 ears with perf/S.G. not testable)

Tympanic Peak Pressure (n = 31 ears)	Number of Ears
Flat (No peak)	15
< -250 mmH_2O	6
Normal	10

Static Admittance (n = 31 ears)	Number of Ears
Flat (No peak)	15
< 0.22 mmhos	2
Normal	14

Jerger Type (n = 31 ears)	Number of Ears
Type A	10
Type B	15
Type C_2	6

Those children whose:

- thresholds were > 20 dB in two or more frequencies
- consistently abnormal T.M.'s on Pneumatic otoscopy
- consistently abnormal Microtymps viz:
- static admittance < 0,22
- tympanic peak pressure < -250 mm H_2O,

were then referred on to their General Practitioners for further investigation and / or referral to an ENT surgeon.

A total of 16 children were referred for further evaluation:

- Bil. MEE/low compliance with normal hearing - 2 pupils
- Bil. MEE with bilateral hearing loss - 7 pupils
- Bil. MEE with Unilateral hearing loss - 1 pupil
- Unilateral MEE and hearing loss - 4 pupil
- Unilateral hearing loss with no MEE - 1 pupil
- Severe hearing loss with S.G.'s in-situ - 1 pupil

Discussion

Various methods of diagnosing middle ear effusions have been evaluated in numerous previous studies. Pneumatic otoscopy used alone has reported sensitivity rates of 94% and specificity rates of between 74 and 78 % for experienced otologists in the diagnosis of middle ear effusions (Cantekin et al 1980). In this study, pneumatic otoscopy showed a sensitivity of 97% and specificity of only 9%. Microtympanometry in this study showed a sensitivity rate of 90% and a specificity rate of 22%. Standard tympanometry has a reported sensitivity rate of 89 % and a specificity rate of 75 % (Zielhuis et al 1989). This study showed a sensitivity of 91% and specificity of 26%.

Tympanostomy (myringotomy) is the absolute means of detecting MEE and explanations for failure to find fluid at surgery include displacement into the Eustachian tube by anaesthetic gases, or positional displacement into the mastoid cortex. Both these mechanisms may be possible with serous effusions but seem less likely with mucoid effusions. Another possibility is that these ears represent those with a temporary Eustachian tube dysfunction.

Fluid was found at myringotomy in 78% of ears, the fluid being categorised into serous (24%) or glue (54%) according to its consistency.

The issue as to whether inclusion of tympanometry with results of pneumatic otoscopy increases sensitivity and specificity is debatable. Cantekin et al (1980) and Mills (1987) found that tympanometry increases both values significantly while Toner and Mains (1990) found no increase in predictive value. In this study the combination of standard tympanometry and pneumatic otoscopy yielded sensitivity rates of 94% and specificity rates of 17 %. The combination of Microtympanometry and pneumatic otoscopy showed values of 94 % and 15 % respectively.

Standard tympanometry agreed with myringotomy in 79 out of 103 ears (77%) where type A and C1 would indicate dry ears and C2 and B would indicate middle ear effusion. A large portion of type B viz.14 out of 80 ears, revealed no middle ear effusion. A surprising finding is that 5 out of 8 ears with type A revealed some fluid in the middle ear. Type C1 would seem to indicate dry middle ear and C2 an effusion.

Microtympanometry agreed with myringotomy findings in 77 ears (75%) - an accuracy equal to that of standard tympanometry. A surprising finding however was that the individual parameter of "gradient" was of very little assistance in the diagnosis. Indeed in a high percentage of cases no gradient reading was obtained, despite a tympanometric profile being obtained. This study has used a low static admittance (< 0,22) or a tympanic peak pressure < -250 mm H_2O to indicate an effusion.

When comparing the individual parameters of standard and microtympanometry, this study has shown that amplitude and static admittance correlates very well. Tympanic peak pressures and Jerger type have a significant correlation as well.

The influence of anaesthetic gases on the post-induction microtymp findings is significant in that 12 out of 103 ears converted to type B after induction - this can also be considered due to positive pressure created with assisted ventilation. In 4 ears, type B converted to type A and to type C1 in 1 ear. The vast majority of type B (77 out of 82 ears), however, remained constant.

The length of anaesthetic time had no influence on the type of fluid obtained at myringotomy. This would seem to contradict the notion that serous fluid would more easily be cleared from the middle ear cleft.

The incidence of persistent middle ear disease in the Barkly House Pre-school screening part of this study was 24 out of 236 ears (10%). Children with persistent bilateral middle ear disease suffer from impaired language development, especially of verbal expression as shown by Zielhuis et al (1989). Whether this results in permanent deficit in language skills is uncertain. Studies have shown that children with impaired hearing attending classes in ordinary schools, show considerably more maladjusted behaviour than children with normal hearing (Brooks 1976).

Children with normal hearing from culturally disadvantaged backgrounds tend to be linguistically retarded relative to those from rich cultural backgrounds. To a child from a home with a high level of acoustic stimulation, the hearing loss associated with middle ear effusion may be a minor handicap, but to a child from a deprived background it may give rise to more serious problems.

Medically, educationally, psychologically and socially therefore, it seems highly desirable that middle ear effusion should be discovered at the earliest opportunity so that treatment may be initiated. Unfortunately, present methods of detection do not appear to be effective in meeting this goal.

Pure tone screening is markedly lacking in sensitivity in detecting middle ear abnormalities.

A number of studies have shown the increased effectiveness of impedance measurement in detecting persistent middle ear disease. However, indiscriminately employed impedance testing may create as many problems as it solves. To increase the efficiency of a screening procedure, repeat testing at suitably chosen intervals is recommended.

The high incidence of spontaneous resolution of middle ear disease negates the use of a single screen to evaluate this condition. This study has employed a staged procedure in which the same population of children was screened more than once. This would be less likely to miss serious middle ear disease and at the same time not overload the E.N.T. services of any region.

The objectivity and reliability of tympanometry make it a very useful tool in mass screening. The problems of acceptability, ease of usage and test time have more than adequately been solved with the use of the Welch Allyn Microtympanometer which this study has shown to be a very reliable and user-friendly instrument.

Conclusions

An excellent correlation exists between microtympanometry and standard tymanometry with regard to Static admittance, tympanic peak pressures and Jerger type.

Pneumatic otoscopy correlates very well with both microtympanometry and standard tymanometry and remains a very accurate method of predicting the presence of a middle ear effusion and should be used by all clinicians.

The Welch Allyn Microtympanometer is as accurate as standard tympanometry in predicting middle ear effusion. It's reliability, objectivity, ease of usage, speed of use and portability make it an suitable tool for use in both the Out-Patient environement and in the mass screening of middle ear disease in Pre-schools.

In this study the individual parameters of microtympanometry and standard tympanometry most useful in making a diagnosis of middle ear effusion is Static admittance < 0,22 ; tympanic peak pressure < -250 mm H_2O and Jerger type B and C2. The parameter "gradient" is often not obtained and correlates poorly with myringotomy findings of middle ear fluid.

The influence of anaesthetic gases on post-induction microtympanometry is evidenced in that although most Type B tympanograms remained constant, 5 ears converted to Type A\C_1. Surprisingly, 12 of the 103 ears converted to Type B, but this can also be considered due to positive pressure ventilation.

The "dry tap" incidence of 20 % in this series correlates well with world literature and implies the effects of nitrous oxide during anaesthesia.

The decision to insert ventilation tubes should be based on a combination of history, clinical assessment, pneumatic otoscopy and pre-operative impedance testing.

The serial screening of pre-school children is recommended and should include impedance testing in addition to the sweep audiometry already employed in these schools. This would ensure that the more common conductive hearing losses as well as the sensorineural hearing losses would be identified and attended to expediantly. The Welch Allyn audioscope is a suitable method for assessing pure tone thresholds in a mass screening environement in children older than 4 years of age.

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